Modified Epc Global Network Architecture of Internet of Things for High Load Rfid Systems

Atishay Jain[1] , Ashish Tanwer[2]
Computer Science Department Thapar University, Patiala – 147001, India
Email: atishay811@gmail.com
Electronics and Communication Department, Thapar University, Patiala – 147001, India
Email: ashishtanwer@gmail.com

***Abstract*- This paper proposes a flexible and novel architecture of Internet of Things (IOT) in a high density and mobility environment. Our proposed architecture solves the problem of over-loading on the network by monitoring the total number of changed objects changing global location crossing the fringe boundaries rather than the actual number of objects present or those that move within the local area. We have modified the reader architecture of the EPCglobal Architecture. The components and the working of the model has been illustrated in detail. We have also discussed the physical implementation of our model taking the examples of a smart home sample application and the performance results have been tabulated and represented graphically.**

***Index Terms*-- Internet of Things, RFID, Smart Home Application, Modified EPCGlobal Architecture**

I. INTRODUCTION

The Barcode for tagging items is being replaced by RFID, the new generation Auto ID technology which is a realtime alternative that uses wireless communication to uniquely identify and track an object. It was invented in 1948 and was first-used during the IInd World War by the US Army for identification of friend or foe (IFF) aircrafts. The technology has found usage in many industry sectors and application like airline baggage tracking, automated vehicle identification and toll collection. A RFID system basically consists of a Tag, a Reader and an antenna. The RFID Tag is a transponder with a silicon microchip for storing large amounts of data which is used to uniquely identify the tagged item. Tags can be either active or passive. Passive tags are read only, gain their power from that generated by a reader. The reading range is typically shorter up to 30 feet (3 meters) and the data storage capacity is comparatively less (96/128 bits) as compared to active tags. Active tags have both read/write capability and are powered by means of battery. This battery-supplied power enables data to be read and written on to a tag and thus gives it a greater reading range up to 300 feet (100 meters) and large data storage capacity (128 KB). Some popular frequency ranges or RFID and their applications are given in Table1.

There are a number of existing (ISO) and proposed RFID standards (EPC Global) that have different data content, use different protocols and have different applications as shown in Table 2. With the adoption of Gen 2 ePC (UHF) standards, the adoption of RFID systems is now a major tool for supply chain management.

TABLE I:
RANGES AND APPLICATIONS OF RFID

Frequency Range	Characteristics	Applications
Low Frequency 125 – 300 kHz	Short range (To 18 inches) Low reading speed	Livestock ID Reusable containers
High Frequency 13.56 MHz	Medium range (3-10 feet) Medium reading speed	Access Control Airline Baggage ID Library automation
Ultra High Frequency 400 MHz–1 GHz	High range (10 – 30 feet) High reading speed Orientation sensitive	Supply chain management & Container Tracking
Microwave Frequency > 1 GHz	Medium range (10+ feet)	Automated Toll Collection Vehicle Identification

TABLE II:
RFID STANDARDS

Specification	Description	Frequency
ePC UHF Class O	64-bit factory programmed	900 MHz
ePC UHF Class 1	96/128 bit one-time programmable	860-930 MHz
ePC HF Class 1	96/128 bit one-time programmable	13.56 MHz
ePC UHF Gen 2	96/128 bit one-time-Programmable	860-960 MHz
ISO 18000-3	Item Management	13.56 MHz
ISO 18000-4	Item Management	2.4 GHz
ISO 18000-6	Item Management	860-960 MHz

The RFID reader can be

- Fixed RFID reader like UHF standard
- Multi antenna RFID reader for supporting several appliances and even can be
- Handheld mobile RFID (MRFID) readers

The internet of Things (IOT) is a networked interconnection of objects. It is global expansion wireless Electronic Product Code (EPC) network implemented through RFID tags [3] or QR Codes.

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An EPC number essentially contains:

- Header, which identifies the length, type, structure, version and generation of EPC
- Manager Number, which identifies the company or company entity
- Object Class, refers to a stock keeping unit or product SKU
- Serial Number, which identifies a specific item of the Object Class being tagged.

II. BACKGROUND

EPCglobal has developed the Object Name Service (ONS) [4], a mechanism which makes use of the Domain Name System (DNS) protocol [5] to discover information about a product and related services from the Electronic Product Code (EPC) and is used for the resource addressing of Internet of Things. The EPC is first encoded to a Fully Qualified Domain Name (FQDN), then existing DNS infrastructure is used to query for additional information. This procedure makes use of the Name Authority Pointer (NAPTR) DNS record [6], which is also used by E.164 NUmber Mapping (ENUM) [7]. Ubiquitous ID Center (uID Center) brings forward similar resource addressing service named uCode Resolution Protocol (uCodeRP) [8], which also utilizes the protocol similar to DNS.

We are proposing ONS based a novel architecture of Internet of Things (IOT) implemented using RFID network. Our proposed architecture solves the problem of over-loading as the load on the RFID Tag reader is the total number of changed objects rather than the actual number of objects present as described in Section-II.

III. RFID NETWORK ARCHITECTURE

EPCglobal is a joint venture between GS1 (formerly EAN International) and GS1 US (formerly Uniform Code Council). The organization has created worldwide standard for EPC, RFID and the use of the Internet to share data via the EPCglobal Network.

Fig 1 shows the EPCglobal Network Standards given by EPCglobal. EPCglobal Network has following components

A. Tags (Transponder) with EPC

Tags follow coding standard of EPC tag information. The EPC coding scheme provides differentiating codes [1] for each object of RFID network. Air interface protocol (GEN 2 AIP) regulates communication between the reader and the tag). Tag data translation protocols converts EPC information to Internet compatible format

B. EPC enabled Reader (Interrogator/Scanner)

Reader follows standard reader protocol to exchange data between EPC-capable middleware Reader management specifications are used to configuration readers.

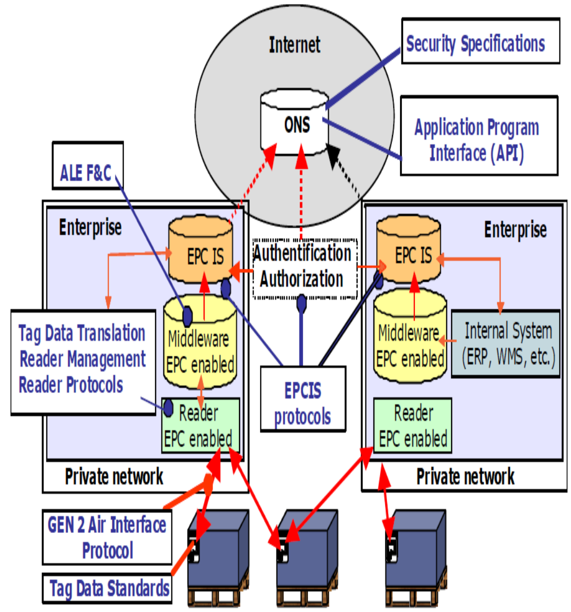

Fig 1: EPCglobal Network Standards (Source: GS1 Germany/EPCglobal)

C. Object Naming Service (ONS)

ONS is the network service system, similar to the DNS. This server will contain all EPC numbers and their associated IP addresses. ONS points out the specific EPC-IS server where the information being queried. It has standard security specifications and API.

D. EPC Information Service (EPC-IS)

EPC-IS is a software component to communicate with the EPCglobal Network and the ONS server. It stores the information processed by EPC middleware and query related information. EPCIS protocols manage storing and accessing of EPC information via the EPCglobal Network)

E. EPC middleware (Savant)

Program module or service with a series of specific attributes, which is integrated by users to meet their specific needs. The most important part of EPC middleware is Filter and collection Application Level Events (F&C ALE).

Our proposed RFID based Internet of Things network architecture is based on the original EPCglobal Network architecture and has some specializations as explained below:

RFID Tags: The RFID tags are attached to each object that is to be identified as shown in Fig 3 (a). The RFID tags used for our purpose are passive and are in inactive state and need to be woken up by a wake-up call when in radio range of an active Tag Reader.

Tag readers (Master and Slave): Our system has two types of Tag Readers –Master reader and Slave reader [2]. The master reader is a conventional powerful fixed active reader with a direct fixed or wireless connection. It initiates a read process in the slave reader and wakes up any passive tags for power-up or any other service initiation. In

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addition, it collects the item-level information and forwards it to the back-end for further processing. Fig 2 shows the placement of Master and Slave Tag Readers. The Master Tag readers are placed at entry/exit points while Slave Tag Readers are in Blocks.

Apart form these, for monitoring precise location of each object within the region a special transmitter is used to call the wakeup calls on the tags that is placed at the boundary of the block containing the Slave Readers. The transmitter has a special antenna to focus the beam straight so that the tags within the region of the slave reader only get activated when they cross the block boundary. To minimize costs, these transmitters do not have readers as more accurate location can be judged with te slave due to the focusing of the beam in a transmitter(marked as red lining in figure 3(a).

The Master reader communicates with both ONS and Inventory database in two different states as shown in Fig 3 (b). The proposed database is used for inventory management in the system with many records. It is responsible for maintaining information as cache for reading purposes.

We have made following assumption in proposing our system architecture:

1) The number of RFID objects in the block is very large.

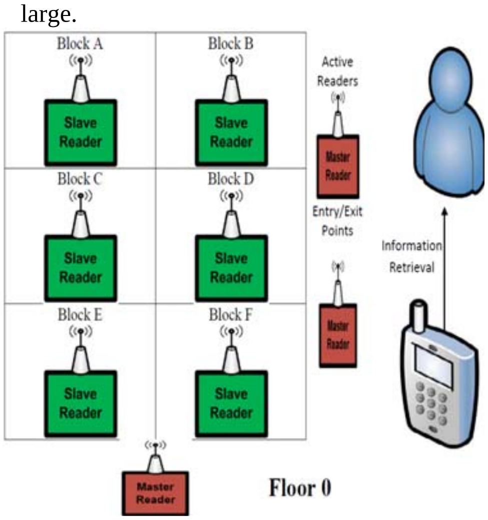

Fig 2: Placement of Master and Slave Tag Readers at Floor 0 of a Building having 6 Blocks (A-F)

2) Most of the objects are stationary for most of the time.
3) The block size is such that the movement of object within the block is insignificant.
4) There are a fixed number of entry/exit points within the region. The objects can get in or go ou through the region.
5) The objects can move within the blocks of a region.
6) Each object has a unique RFID that can be interpreted at the Object Name Server (ONS).

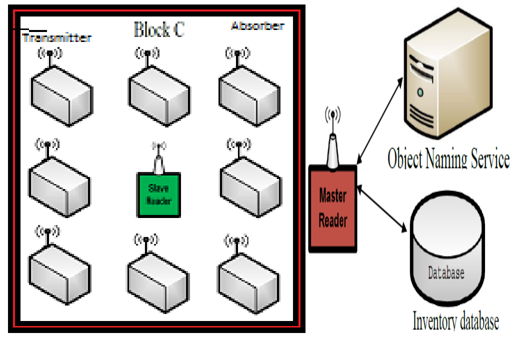

Fig 3 (a) Block Structure (b) Communication of Master reader with ONS and Inventory database

IV. NETWORK WORKING

The objects labeled with the RFID tags will be located within the closed region divided into blocks each of which having a slave reader to identify the items whose RFID tags can be activated by the slave reader as well as the transmitter located at the block boundary. This slave reader will in normal working situation be in inactive state. The slave readers can be present alone in a block or networked as tiered arrangement of aggregation. The slave readers will be connected to a master reader which would act like an aggregation server for the slave reader readings and will pass the information the ONS and used the inventory database for caching. The connection of the slave to the master reader can be wireless, direct wired or switched with redundant cabling based on the use case. The slave readers located at the entry/exit point will remain active and function as the primary readers for data update. The transmitters located at the boundary of a block will remain active but will have a limited range and will activate objects that cross the block boundary.

A. *Case I Initial Setup / Refresh*

The initial setup will consist of the master reader instructing the slave readers to active state (by sending wake-up call) one by one which in return will force the RFID tags of all the objects in the state space (region) into the active state (by their wake-up calls). The slave readers will transmit the read RFID tags to the master reader which will, with the help of the ONS cache the location of the objects in the inventory server. The field will include the RFID, the object description, the user identification number (in case it is different from the RFID) as in the case of a local repository of the ONS. Alongside this, the location as well as the block number of the objects will be saved.

B. *Case II Reading*

The reading of a tag involves getting the data from the inventory database and returning the information.

C. *Case III Movement of object within the Region*

In case the object move within the region from one block to another, the transmitter at the block periphery with activate the tag and the slave reader in the new block will

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read the tag values. Only the location will be updated within the database.

D. Case IV Removal of Object

In case of removal of object, the active readers the exit points will activate the RFID tags. These RFID tags will send the information to the readers which will match it inside the inventory database. The deletion of information can occur directly from the inventory database for the object. In case of an object absent, it indicates that the data inside the database needs refresh. The primary difference between the reading in case of movement and removal is that, in case of removal, the transmitter cum receiver makes sure that the object is removed, while in case of movement, the trade-off between accuracy and precision is applied by moving the slave reader away from the transmitter for more precision.

E. Case V Addition of Object

The addition of object to the system through the entry points will involve the wakeup of the RFID tag by the entry points. The entry point reader will inform the master to wake up the corresponding slave to a reading state where it reads active tags but does not transmit the Wake-up Calls. The newly entered object will be in the active state and will be transmitting the RFID information. This can be used to track its new location by the slave readers without activating the other objects and thus preventing energy wastage or clatter. The fringe transmitters will continue to function normally to locate the exact location within the region.

V. SMART HOME APPLICATION

The high level architecture of the smart home is similar to figure 2 and 3. There are two possible arrangements for the architecture in a smart home.

A. Each room as a block

In this arrangement, the assumptions that hold are that the RFID objects in a room are not of a very large number and there is no major ovement of objects between the rooms. The RFID tagging is used to detect whether the object is at home and in which room was it taken last. The advantage of this structure is lower costs though it is impractical for real life implementation. In figure 4, the red RFIS reader is the active reader that will activate the RFID tag when the item enters the house. The green slave readers are placed such that the entire house is in the reading range of the slave readers. It does not matter in which room they are placed as long as we know the entire house is covered. The active RFID tag will provide its details and location while the object is moved to its final position. This position will be indicated as the objects' position in the reader. It is assumed that the entry/exit point in the house is only the main door and not the windows. The transmitters wil be placed within the doors of the room. These will enable us to get an idea regarding which room the ojecy currently is.

B. Each room as a RFID segment

In this arrangement, each entry point within a room acts as an entry point and each room itself acts as a complete RFID system. The main server that accounts for all the rooms can be located anywhere and can run separate blocks of code for each room. The transmitters will be located within blocks inside each rom giving very precise location of an object within a room. Though, it could have been done in the previous architecture increasing the block density but having a huge number of blocks in a system would increase the calculations costing heavily in case of a requirement of a refresh. This architecture, though will be able to handle very large number of objects within a room as well as an account for a more accurate position of an object within the room the object was detected in.

The second architecture can be used to provide nearly accurate information for all the devices in a smart home. If the RFID objects are equipped with sensors that detect movement and transmit information, the system though optimal, would get out of practical considerations for size and cost.

Fig 4 shows the possible arrangements of RFID Tags readers based upon our architecture. Arrangement 1 used some master tags (colored red) and some slave tags (colored orange). If we add the master readers which are indicated in orange, it turns into the arrangement 2. The densite of the slave tags would have to be increased in that case within the rooms. The RFID tag of the object gets activated as soon as it changes room/enter/exits the house. This is then recorded as it moves across the house. The sensitivity of the system can be increased by increasing the number of density of readers at strategic locations which slows the performance in case of large amount of movements of objects.

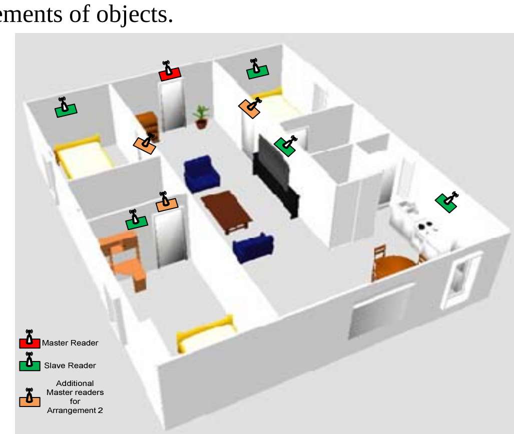

Fig 4 Arrangement of RFID Tags in Sweet Home

An example of the strategic location could be above the dining table as it marks an entrance of a different part of the main hall – the kitchen. The correct room as well as the last known position of the object is available in this setup.

VI. PERFORMANCE RESULTS

For the implementation of our architecture the performance characteristics of master and slave RFID tag readers should be shown in Table 4 and corresponding Fig

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6. As shown in figure, the number of tags read by slave reader should decrease steeply with increase in reading distance so that two slave tag reader cannot interfere with each other. On the other hand, the master tag reader should have long range so that it can make connection with all the slave readers.

TABLE III:
READING PERFORMANCE (%) OF MASTER AND SLAVE TAG READERS

Reading Distance (in ft)	Tags Read by Master Reader (Entry Exit Points)	Tags Read by Slave Reader (On activation)	Tags Enabled for Slave Reader (Using Transmitter)
1	100%	100%	100%
2	100%	80%	60%
3	95%	55%	40%
4	90%	45%	15%
5	85%	35%	-
6	80%	20%	-

The higher range of master readers as illustrated in the figure is a prime requirement for the system to be effective. No object entering the system should be able to skip the master reader. Ideal placement for the master reader would be overhead or along the sides of the entry/exit points. The sphere of 100% reading performance should cover the entire area of these points. Additional readers networked as one can be used to boost performance. The performance curve indicates that the slave reader should also be placed to make blocks (Fig 3a) keeping them at 4-5 feet from each other. This range largely depends on the tag density (here 20 tags/feet) for higher density increases clutter and disturbance. Also for slave readers, the density refers to the number of active tags within range rather than all tags, in case of which, there could be 1-2 tags in a slow moving system within the range of a tag reader. The transmitters have to be placed to form an interlocking block. They are made especially to have little effect on object. It is worth mentionaing that the object may be able to bypass the transmitter in rare cases because of the vertical range, but would never be able to pass out of the system unnoticed from the master readers at the entry and exit points. The density of the mesh of transmitters and the slave readers would largely depend on the usiness case and the accuracy requirement of the system, which is not that critical in a smart home as in stock movement tracking applications.

VII. CONCLUSION

RFID offers new levels of visibility for companies that want to track physical items between locations. Our model with some modifications can be used in the retail supply chain where the goods tagged at the point of manufacture can now be traced from the factory to the shop floor, providing a real time view of inventory for all supply chain partners.

Internet of Things (IOT) is future network of all objects and it can be implemented using RFID. Its standards are given by EPCglobal. Our proposed architecture is based on EPCglobal Network with some assumptions and modifications.

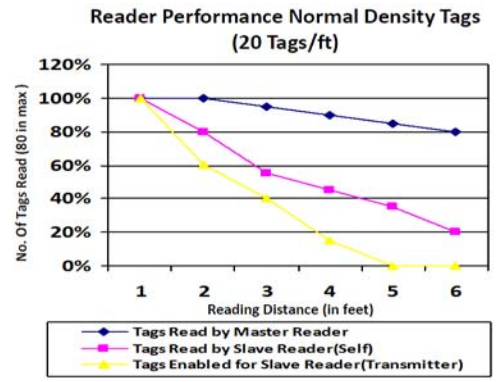

Fig 5: Reading Performance comparison of master and Slave Tag Readers

It solves the problem of over-loading as the load on the RFID Tag reader is the total number of changed objects rather than the actual number of objects present. We have also discussed the way to implement our architecture for sample applications smart home. Future work in this system could be to incorporate a means for tracking movement of objects within the system. Another extension could be to provide a placement criterion for the slave readers, which in the current architecture use the overlapping structure similar to the placement of wireless access point for internet access. The major difference in the systems is the size of the slave readers which is much smaller, with smaller ranges as compared to access points. Also, slave readers can be arranged without wired connections to contact and share information wirelessly over the network. Awareness of RFID technology and Internet of Things concept can benefit industry and home automation globally.

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